Bechtel National Incorporated

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Introduction

This report represents the final product in response to the SNL contract to evaluate the feasibility of developing a small, modular biopower system. The effort supports the U.S. Department of Energy's (DOE) Biomass Power Program, whose goal is to develop small modular biopower systems that are fuel-flexible, create minimal impact on the environment, are efficient and simple to operate, and fall in the power generation range of 5 kW to 5 MW electric for domestic and international markets.

The study includes quantifying the domestic and international markets requiring industrial biomass power generation systems ranging between 800 kW and 1600 kW, identifying and quantifying the biomass fuels available in these markets, and evaluating these markets from economic and environmental standpoints. The preliminary system design expands on the present introductory design by identifying technical issues imposed by the market such as the appropriate system size, modularity requirements for transport, and local installation constraints. Further, the effort also included pursuing strategic partnerships with engine manufacturers to package an entire small modular biopower unit.

The Bechtel Technology and Consulting group of Bechtel National Inc. (BNI) led this effort with its subcontractor PRM Energy Systems, Inc. (PRME) of Hot Springs, Arkansas and its affiliate Primenergy of Tulsa, Oklahoma.

The basis for the small modular biopower system is the commercial KC gasifier. PRME owns the rights to the technology. PRME has been providing commercial KC gasifiers for industrial applications since the early 1980s. To date PRME has installed 18 of these gasifiers in a range of sizes from 8 MMBtu/h to 290 MMBtu/h. These installations provide process heat, process steam, electricity, and in many cases a combination of all three energy types.

Potential Markets

A review of the present combustion turbine and reciprocating engine markets indicates that the largest market for distributed engine systems is in the 5- to 2000-kW size range. Sources indicate that most of the combustion turbines in 1996 to 1997 were shipped to the Far East, whereas the largest reciprocating engine markets appeared to be in North America and Europe.

Rice mills constitute a target market for the KC gasifier SMB system. Market studies show that Malaysia has more than 70 mills that could generate 800 kW or more, the Philippines and Thailand more than 100 mills each that could support an 800-kWe system. Information regarding the exact size of the mills in India and China was not obtained; however, the two countries produce more than 50% of the world's rice. Given that both countries have power shortages, they have potential markets for the SMB system.

The lumber industry also represents a unique market in which a waste resource could be used for power generation. Plywood factories normally require more power than sawmills and may support a 500- to 800-kWe system more readily in a captive power setting than would a sawmill. The Indonesian plywood factories studied require an average diesel system of 850 kWe. The waste residues from the factories can support 850-kWe to 1.5-MWe systems.

Most clients for the SMB system can maintain a system that requires operations and maintenance similar to a diesel generation system. The technical capabilities and spare parts will be considered in the SMB design. Load profiles for potential clients and typical industries, which indicate that a turndown ratio of 50% to 60% is required, were reviewed.

Fuel Resources

Abundant resources exist for the SMB KC gasifier system in the form of crop or food processing residues. The KC gasifier can operate on 17 fuel sources, of which rice hulls, rice straw, wheat straw, lumber, corn cobs, and switchgrass residues were reviewed. Residues from the palm oil process were also estimated; however, empty fruit bunches (EFB) and palm nut shells have not been proven in the KC gasifier. The amount of residue and their subsequent potential power production were estimated based on crop production and independent studies. Table 6 summarizes the estimates of the total resource and power available. Electricity conversion efficiencies range from 18% to 22% depending on the resource, not taking into account the potential thermal energy available from the exhaust. The authors do not claim that the potential energy translates to market potential. The information indicates only the potential power production.

Table 6. Fuel Resource Quantities and Energy Production Potential

Crop/resource	1000 tons	Potential MWe
Rice Hulls	106900	5580
Rice Straw	534700	33743
Wheat Straw	579588	30263
Corn Cobs	633600	112540
Wood Residue		45000
Cotton Gin Trash	48183	2925
Switchgrass	84400	8346
Empty Fruit Bunches	7440	402

Financial Analysis

Financial analysis entails funding the new concern and determining the true costs of the SMB unit. Working capital requirements will be sought from a variety of sources including equity funds, potential strategic investors, and venture capitalists. These sources will be assessed, tested, and prioritized and the most advantageous working capital source will be chosen.

Detailed costs for the SMB unit based on manufacturing, assembly, installation, operations and management, and fuel costs have been established. The nominal delivered electricity cost for the units, under the scenario where there are no fuel costs, is approximately 4.9¢/kWh for the 1600-kW unit and 8.0 ¢/kWh for the 800-kW unit. These prices assume a 7.5% interest rate for a 7-year term and 25% equity. According to published equipment prices for competing distributed energy technologies, when fuel prices exceed $2/MMBtu on combustion turbine units and $4/MMBtu with diesel generation systems, the 1.6-MW SMB unit has a lower levelized energy cost over a 15-year book life.

System Design

The SMB system based on the KC gasifier has been designed in two sizes, 800 kWe and 1600 kWe. The model KC8 gasifier will be included in packaged systems, that require 800 kW or less, and be designated "Model KC8-800." The model KC12 gasifier will be included in packaged systems that require 1600 kW or less and be designated "Model KC12-1600." The SMB systems consist of the gasifier system, producer gas cleanup, and a spark-ignited internal combustion engine (ICE).

The KC gasifier system typically includes the following equipment: fuel metering bin, continuous flow weigh meter, reactor/gasifier, refractory lined reactor gasifier, cooling water system, water-cooled ash discharge conveyors, multi-zoned air supply, rotary feeders, and instrumentation required to provide automatic control over the process. The entire gasification/combustion process, from metering to ash discharge, can be controlled manually or electronically.

In the producer gas cleaning system, the first preparatory step is cooling the producer gas from the evolution temperature. The initial cooling is accomplished by indirect heat exchange with air or water. Secondary cooling, ash, and initial tar are removed by direct liquid scrubbing. Exiting the liquid scrubber, the gas is finally mechanically scrubbed of tar, cooled in a heat exchanger with cooling water from external cooling tower, and slightly boosted in pressure. The clean producer gas is premixed with heated combustion air before being injected into the ICE.

The ICE is a V-16 with a dry turbo-compressor and electronic ignition. The engine is started with a 24-volt direct current starting motor. The engine is cooled by heat-exchanging internal cooling water with radiator cooling. All necessary pumps, exchangers, piping, and cooling water tower are included. Each engine is direct coupled to an electrical generator and each engine-driven generation set is mounted on a common frame.

The integration of the gasifier and gas cleanup system to produce a consistent quality producer gas to sustainably run an ICE has not been demonstrated. The future work and efforts should be directed toward demonstrating reliable power from the KC-8 system and tie-in with the grid.

Details regarding the producer gas production, process flow charts, and process flow diagrams are provided. A preliminary analysis of the gas produced from the KC gasifier indicates that the producer gas may be an acceptable fuel for a molten carbonate fuel cell with preprocessing of the gas. Fuel cells may be potential power generation sources in an SMB once the technology becomes fully commercial. They are not considered viable options at this time.

Both the model KC8-800 and the model KC12-1600 have been designed so they can be packaged for export and transported by ship, rail, or truck in standard containers. Research indicates that infrastructure is present for most probable sites. The modules have been designed to maximize shop assembly and minimize field erection requirements.

Environment and Safety

The SMB system based on the KC gasifier is designed to meet the World Bank General Environmental Guidelines. Initial tests indicate that the SMB unit will meet No_x and SO_2 emission limits. Particulate, solid, and liquid waste limits will be tested in Phase II. Design modifications will be made if necessary to meet the General Environmental Guidelines.

Impacts from manufacturing, shipping, installation, maintenance, operations, and decommissioning are similar to those of combustion turbine-, and diesel-generated power units of similar capacities. Operations have

positive impacts on the environment by displacing fossil fuel with an agriculture residue. The agriculture residue is a sustainable, renewable resource. The CO_2 emitted during the conversion process is absorbed by subsequent crops grown.

The SMB unit based on the KC gasifier is designed with state-of-the-art instrumentation and built-in safety interlocks to provide automatic operation and protect personnel and equipment in the event of upset operating conditions.

Future Development

KC-Systems is in an excellent position to capitalize on the vast market for SMB systems. The company's products are based on proven technology and its founders have a long track record of implementing successful biomass projects in the national and international marketplaces. The company's vision, mission, and goals are realistic, sound, and achievable.

The initial management team is made up of experienced professionals with positive and aggressive attitudes toward the success of this new venture. Several contacts with potential marketing and development partners are in place and require only further evaluation and negotiation. Supported by its parent companies, the new entity can start up and grow without additional capital; however, to expand rapidly and achieve its maximum potential, additional capital will likely be necessary.

KC-Systems' products are competitive in most markets. The company's initial system sizes will span approximately one-third of the total current market for competitive fossil fuel systems. The systems modularity and future scaled-up versions increase its coverage to more than one-half of the marketplace.

KC-Systems planned mode of production and operation is sound. The initial manufacturing of the gasification systems in Tulsa will ensure good quality control and efficient production. Adequate facilities are currently available for the first two years of production. The potential future procurement and manufacturing of portions of the systems on the local economy may provide opportunities for lowering costs.

The sales and distribution plans will provide for quick penetration into the target markets. The opening of dealerships within these markets will give immediate access to the dealers' current clients and provide for superior customer service.

The risks for this business venture are manageable.

KC-Systems ***presents a tremendous opportunity for its founders, partners, dealers, and suppliers to be the early leaders in the SMB field of renewable energy.***